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# THE INNER ACCRETION DISK OF BLACK HOLE A0620-00

NASA Grant NAG5-1982

Final Report

For the Period 1 June 1992 through 31 May 1995

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February 1995

Prepared for:

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A paper detailing the work accomplished under Grant NAG5-1992 is scheduled to appear in the 1995 March 20 issue of The Astrophysical Journal. The paper is entitled: "The Dim Inner Accretion Disk of the Quiescent Black Hole A0620-00." The authors are J.E. McClintock, K. Horne & R.A. Remillard. A synopsis of the paper with emphasis on the ROSAT data analysis and results follows.

## 1. INTRODUCTION

In the fall of 1975, the X-ray nova A0620-00 was the brightest celestial X-ray source. During outburst it was identified with a blue star of 12th magnitude. Fifteen months later the optical counterpart had returned to its preoutburst brightness, V = 18.3. Its quiescent spectrum was found to consist of two components which are about equally bright in the V band: an approximately K5V stellar spectrum and an emission-line component that is due to an accretion disk.

Photometry and spectroscopy in quiescence revealed a 7.75 hr orbital period, a large velocity amplitude for the K5V secondary, and a corresponding mass function of approximately 3 $M_\odot$ (McClintock & Remillard 1986). This large mass function established A0620-00 as a leading black-hole candidate, a conclusion that has been confirmed and extended (e.g. Marsh, Robinson, & Wood 1994).

## 2. X-RAY OBSERVATIONS, DATA ANALYSIS, & RESULTS

We observed the field of A0620-00 with the ROSAT PSPC imaging detector for $3 \times 10^4$ s. The observations, which were made during five days in 1992 March, provide good phase coverage of the 7.8 hr orbital cycle of A0620-00. We determined the count rate of A0620-00 using the PROS software and a single X-ray image that incorporates the entire $3 \times 10^4$ s of data. The total number of net source counts detected in $3 \times 10^4$ s was 39±8 counts in PHA channels 10-24. In order to perform a spectral analysis with so few counts, we used the maximum-likelihood method. We assumed, furthermore, that the disk radiates as a blackbody, as suggested by theoretical studies of classical and relativistic disks, and we fixed the interstellar column density at $N_H = 1.6 \times 10^{21}$ cm$^{-2}$.

We used the X-ray spectral fitting package XSPEC to constrain the blackbody temperature and source luminosity. In a likelihood analysis it is not permissable to subtract the background. Therefore, we fitted the source and background regions simultaneously. Both the background spectrum and the source spectrum were well fitted by blackbody models. With the background parameters fixed at their best values we used the measured values of the source parameters and the XSPEC routine "fakeit" to simulate 1000 synthetic source spectra. Fitted parameters (temperature and luminosity) were derived for each of these spectra in exactly the same way they had been derived for the observed spectra. The following are the best-fit values of the source temperature and luminosity (for d = 1 kpc):

$$kT_x = 0.16^{+0.10}_{-0.05} \text{ keV}$$
$$L_x = 6^{+8}_{-2} \times 10^{30} \text{ ergs s}^{-1}$$

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## 3. DISCUSSION OF THE X-RAY RESULTS

The observed X-ray lumonosity is very modest, $L_x \approx 6 \times 10^{30}$ ergs s$^{-1}$, and one must consider the possibility that it all may be generated in the corona of the rapidly-rotating K5V secondary star. However, this appears to be unlikely. Studies of rapidly rotating K dwarfs indicate that $L_x$ never exceeds $10^{30}$ ergs s$^{-1}$, whereas $L_x$ (A0620-00) $> 3 \times 10^{30}$ erg s$^{-1}$ (90% confidence). Moreover, for the K dwarfs in the Pleiades there appears to be no dependence of $L_x$ on $v \sin i$ (Eracleous, Halpern, & Patterson 1991, and references therein; Micela et al. 1994).

It therefore appears likely that most of the X-ray flux comes from the accretion disk. If all the X-rays come from the disk, then the above luminosity implies a mass accretion rate of $\dot{M}_{BH} \sim 2 \times 10^{-15}$ M$_\odot$ yr$^{-1}$ for a Schwarzschild black hole ($\epsilon = 0.06$). The actual mass accretion rate may be much less if the black hole rotates rapidly or the secondary star contributes significantly to the X-ray flux.

## 4. CONCLUSIONS

Results of observations of A0620-00 with the HST Faint Object Spectrograph are also presented, which show that A0620-00 is very faint in the far-UV band.

In contrast, the *optical* luminosity of the quiescent accretion disk revealed by ground-based observations is substantial. By analogy with dwarf novae, the optical luminosity of the disk ($M_v \approx 7$) and the orbital period of A0620-00 imply that the rate of mass transfer onto the outer disk is $\dot{M}_d \sim 10^{-10}$ M$_\odot$ yr$^{-1}$. This rate is almost 5 orders of magnitude greater than the mass transfer rate inferred for the inner disk, which is given above. There is one model that can explain these discrepant mass transfer rates, and that is the disk instability model. This model has been developed for A0620-00 in detail (Huang & Wheeler 1989; Mineshige & Wheeler 1989). The paper concludes that this model provides the best current explanation of the observational results.

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